DEPARTEMENT TOEGEPASTE
ECONOMISCHE WETENSCHAPPEN

ONDERZOEKSRAPPORT NR 9658

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D/1996/2376/58

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INTERNAL R&D EXPENDITURES AND EXTERNAL TECHNOLOGY SOURCING

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SEPTEMBER 1996

Abstract

The paper examines the two-way relationship between external R&D activities and internal R&D expenditures on a cross-section of Flemish R&D active companies. The analyis extends the classical explanatory variables like size, diversification, ownership structure and technological opportunities to include the impact of various external sourcing strategies. R&D cooperation and to a lesser extent R&D contracted out are found to have a significant positive effect on internal R&D but only if the companies have absorptive capacity in the form of a full-time staffed R&D department. At the same time firms are found to be more likely engaged in R&D cooperation, the more they spend on internal R&D.

Key-words

Internal R&D, external sourcing, cooperation, two-way relationship

° The author acknowledges support from IWT (Project OZM/O&O), DWTC ((IN/01/002), FKFO (Project G.0296.96), EC Human Capital and Mobility Program (CHRX-CT93-0297). Comments from K. De Backere, B. Clarysse, G. Steurs, J. Konings, B. Cassiman are gratefully acknowledged.

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1. Introduction

Innovative strategies have become a central focus in firms' competitiveness in an increasingly global economy. Firms competing in global markets face the challenge and opportunities from the convergence of consumer preferences and the pace and scope of technological change, engaging them in extensive and risky sunk R&D expenditures. As a consequence firms are relying extensively on external linkages. The pervasiveness of networking has become a significant feature in current innovation management practice. In view of the increasing complexity and multidisciplinarity of research, even the largest and most self-contained of organisations requires information from beyond its boundaries. Innovation increasingly derives from a network of companies interacting in a variety of ways, that move beyond traditional R&D contracting. In their strive for access to external know-how, the exploitation of complementarities between partners and sharing of risks and costs, while internalizing spillover effects, firms revert to cooperative modes ranging from R&D consortia, joint ventures, implicit coordination, mutual exchange or "informal" know-how trading (von Hippel (1987)), and this despite the possible higher transaction costs associated with external sourcing (Pisano (1990)).

Ample theoretical and empirical research exists on firm and industry characteristics most conductive to innovation, dating back to Schumpeter's work on firm size and market concentration, and reviewed by Cohen & Levin (1989). But rather than trying to identify any single type of firm that is most innovative, the theoretical and a fortiori the empirical literature is less ample when dealing with complementarities and relationships among firms and other institutions that may facilitate innovation. Induced by influences from evolutionary economics, innovation theory has shifted from the traditional linear innovation model to the interactionist or integrated model (Kline & Rosenberg (1986)), emphasizing technological progress as a result of interaction between knowledge-producing and knowledge-using agents. This new approach is at the heart of the concept of national innovation sytems (Freeman (1987), Nelson (1993) a.o.).

Within this interactionist model, the more specific relationship between external linkages and own in house R&D activitities, remains a complex issue. Although the availability of external technology may discourage -and hence substitute for- own research investment by the receiver firms, there are also arguments to stress the complementarity between in-house R&D and external know-how. Own in-house R&D activities are often indicated as reducing some of the inefficiencies and problems associated with external acquisition, if only because it allows to modify and improve external acquisition. But also external technology is often only available on an exchange basis, certainly in the cooperative types of sourcing. As Baumol (1993) notes "In some cases the arrangement is totally informal, each firm simply expecting full access to the innovation of the rival, with full provision of its own technological advances serving as the quid pro quo" (see also von Hippel (1987)). Furthermore, the capacity to go for it alone increases a firm's bargaining power in negotiating with external partners. Contractor (1983) for instance, finds the licensing fees to be smaller when the receiver firm has a well developed R&D group.

Although external know-how can help partners to capitalize on mutual complementarities, managing external acquisitions is a far from simple task. External information cannot easily enter the closed information system, even when its contribution is unquestionned, because of screening problems in finding and acquiring external information, but also because of problems in implementing external know-how. External information, often felt by own R&D personnel as an implicit indictment of its own R&D, needs to be fit internally, overcoming the 'not invented here' syndrome. Suitable organisational structures and incentive schemes need to be devised to stimulate external learning. Not surprisingly a "learning organisation" has been characterized as an organisation skilled at not only creating, but also acquiring and transferring knowledge and at modifying its behavior to reflect new knowledge and insights (Garvin (1993)). Sen & Rubinstein (1989) identify how in-house R&D can alleviate problems in the various phases of the process of acquiring and implementing external technology. They stress however, that given the many inter- and intra-organisational as well as personal factors hampering the role of in-house R&D groups, an involvement from in-house R&D groups from the start is necessary, moving beyond mere trouble-shooting.

Also Rothwell (1992) stresses that linkages with external sources of scientific and technological know-how are only effective when the organisation exhibits a willingness to take on external ideas, requiring the presence of key individuals, the so-called technological gatekeepers (Allen (1986)). The resulting scale economies in effective external R&D strategies may disadvantage small firms. The specific problems of SMEs in establishing external linkages are tackled in Rothwell & Dodgson (1991). These authors agains stress that a SME's ability to access external know-how is conditioned by its in-house employment of qualified technical specialists and scientists and engineers.

While external linkages considered so far, imply some active involvement or consent from the sending party, the difficulties in appropriating know-how allow for knowledge to diffuse and external know-how to be accessed without any explicit involvement from the sending party and even despite attempts from firms generating know-how to keep this proprietary (Arrow (1962)). Mobility of researchers, reverse engineering are but a few of such phenomena that generates these spillovers (Mansfield (1985)). By now an extensive theoretical literature has developed around the effects of spillovers on own R&D (see De Bondt (1995) for a review), stressing that it substitutes for own R&D in the receiving firm, but that it also reduces own R&D by the sending firm to the extent that it cannot fully internalize all benefits, cf the disincentive effect (Spence (1984)) and this typically despite a market enhancement or cost reducing effect that should stimulate efforts. The size of these effects depend of course on the size of the spillovers and the degree of competition between firms. Also the level of commitment to R&D strategies and the firm's network structure will matter.

Similarly in this literature it is argued that a firm's ability to identify, assimilate and exploit existing external technologies can be enhanced by own R&D (e.g. Harabi (1995)). The notion of 'absorptive capacity' introduced by Cohen & Levinthal (1989) stresses the importance of a stock of prior knowledge to effectively absorb spillovers. In such a setting, the desire to assimilate external know-how creates a positive incentive to invest in R&D. Hence spillovers may rather than diminish own R&D encourage equilibrium industry R&D investments. Also Levin & Reiss (1988) show that when spillover productivity increases, spillovers will stimulate own R&D since the productivity of the latter is enhanced by increases in industry knowledge.

In conclusion external know how may stimulate rather than substitute own R&D activities at least when in-house R&D groups are optimally tuned to absorb effectively external know-how. However, when the technology strategy of a company is not explicitizing the link between in-house development and external acquisition, such in-house R&D groups may hamper rather than stimulate effective external linkages.

When confronting these hypotheses with empirical evidence, the first thing to notice is the relative scarcity of empirical research on the link between external and internal R&D. Gambardella (1991) finds from case studies of a few large US drug manufacturers that firms with better in-house scientific research programs have exploited more effectively outside scientific information. More indirect evidence from the pharmaceuticals industry is provided by Henderson & Cockburn (1996), whose results seem to indicate that there are significant returns to size, with a primary advantage of large firms being able to capture and use internal and external spillovers of knowledge. In biotechnology, Arora & Gambardella (1990) find evidence of large firms with higher internal knowledge to be more actively involved in pursuing strategies of external linkages. However, Pisano (1990) found US firms in biotechnology to be more likely involved in-only in-house R&D in those areas where they have accumulated in-house R&D. Going further back in time, the SAPPHO project, a comprehensive study of the success factors for innovation, already stressed the central importance of external collaboration with users and external sources of scientific and technical expertise. Both formal and informal networks were demonstrated to be important, although the latter appeared to be the most important. Freeman (1991) cites empirical evidence of research associations, as well as licensing transactions, to be used intensively by firms who have their own R&D, thus concluding that these strategies are complementary rather than substituting for indigeneous innovation. Empirical estimates of the size of technology spillovers, measured between sectors or between firms, is provided by a.o. Scherer (1982), Verspagen (1995), Jaffe (1989), Harabi (1995)).

While the litterature as it stands today is only starting to unravel the complex phenomenon of linkages between internal and external R&D strategies, this paper presents an empirical analysis using firm level data of Flemish innovative firms. Given the typically small and open character of the Belgian economy, the analysis will include a special focus on the differential behavior of SMEs as well as affiliates of larger multinational entities. The empirical model is an extension of the classical studies on R&D determinants. Standard explanatory variables like size, diversification, ownership structure and technological opportunity are included to explain firm's expenditures on internally financed intra-muros R&D. The major focus of the analysis is of course on the extension towards external sourcing strategies and their impact on own in-house R&D expenditures. In addition, external sourcing may also have an impact on technological performance, raising innovative output without affecting innovative input. However, given a lack of data on innovative output for the sample, this effect cannot be empirically assessed.

Various modes to acquire externally developed technology are considered in the analysis. Next to buying technology through licensing contracts or embodied in equipment, firms can contract out R&D activities to agents, other firms related or not, private or public research institutions. But avoiding costs and problems of market transactions, firms increasingly revert to cooperative modes of R&D to get access to external know-how. This cooperation may be simple coordination of R&D activities over exchange of information over jointly researching or developing in a research joint venture or consortium. With perhaps the exception of the (poor quality) information on embodied technological purchase, the external sourcing strategies in the empirical analysis are restricted to those involving a consenting position of the sending party. More implicit, informal spillovers are hard to quantify and therefore are excluded in the analysis.

The next section will detail the hypotheses and variables used, while section 3 presents the results. A concluding section summarizes.

2. The hypotheses

2.1. The sample

The data are analysed at the firm level. The sample consists of about 290 Flemish companies, surveyed on their R&D expenditures for the period 1992-1993. The survey only includes companies active in R&D. The long tradition of this bi-annual questionnaire on the basis of the Frascatti-methodology, serving for the OECD statistics, as well as a core of large, regular respondants, improves the quality of the quantative data, collected through this survey.

The sample, which is only representative for R&D active companies clearly illustrate that R&D is a highly concentrated phenomenon in Flanders. Three quarters of the sample companies have less than 200 employees and account for 12% of total reported R&D. The 7.5% of companies in the sample with more than 1000 employees not surprisingly accounts for almost 70% of reported expenditures. Besides two key sectors, the chemicals (include pharmaceuticals) and IT (audio/video and telecom), who account for resp 44% and 33% of reported R&D, a second tier of sectors including electronics, metals manufacturing, software services & food can be identified. Companies from other sectors, 29% of the sample, represent only 3% of reported R&D. About one third of the respondents have a majority of foreign ownership (mostly fully owned). These significantly larger firms account for 84% of total reported R&D. Most of the respondents, 73%, are not diversified outside their Nace 3 digit sector. A more complete discription of the sample and the survey methodology can be found in Veugelers & Steurs (1995).

2.2 The variables

Since the survey gives no information on innovative output, the inputs employed by the company in its R&D process is used as a measure of **technological performance** for the dependent variable. The variable IRD includes the internally financed intra-muros expenditures for each firm for the year 1993. The amounts that firms spend on extra-muros R&D, i.e. in the context of R&D contracted out, is ofcourse excluded on the left-hand side, since they will appear on the right hand side. Also excluded are the amounts received from R&D contracts as well as government subsidies, leaving only the internally financed R&D. For the sample companies, performing R&D for other entities through R&D contracts is rather unimportant. It represents on average 10% of all intra-muros expenditures.

The basic specification to explain firm expenditures on internal R&D is as follows:

$$\begin{aligned} \log IRD_i = {} & a + \log S_i (b + c M_i) + d M_i + e DIV_i \\ & + (f_1 CHEM + f_2 IT + f_3 INFO + f_4 MVEN) \\ & + g \log SUB_i \\ & + \log ERD_i (m_1 + m_2 RDP) \\ & + COOP_i (n_1 + n_2 RDP) \qquad (1) \end{aligned}$$

The variable S_i is a proxy for **size**, measured by sales. Size as determinant of innovative activity is one of the major hyptheses associated with Schumpeter. Economies of scale in R&D, the ability to spread risks over a portfolio of projects and access to a larger pool of financial means, give large firms an advantage over smaller firms. However, flexibility, adaptability, an efficient internal communication process of typically smaller companies allow a more rapid response to external opportunities and threats and may give an edge to smaller innovative firms. The survey results indeed display a U-shaped relation between size and R&D intensity with the smallest, <20 employees, i.e. 20% of the sample, having a sample average R&D intensity of 11%. [1] The logaritmic specification will support the Schumpeterian hypothesis with b>1 (see Kamien & Schwartz (1982) for a more detailed discussion). To avoid possible simultaneity problems, with R&D determining firm size, sales in 1992 is used, i.e. one year lag vis-à-vis the dependent variable.

[1]. Note that this high R&D intensity should not be extrapolated outside the sample of innovative firms to all small firms.

With R&D remaining a very centralized function within a **multinational company**, the R&D strategy of subsidiary companies in host economies may be seriously affected positively or negatively by the parent company (see Veugelers & Vanden Houte (1990)). To test the differential behavior of subsidiaries, a dummy M_i =1 if the firm is majority foreign owned, else zero. Given that subsidiaries are typically larger firms and belong to larger concerns, there is also an interaction with the size variable. The coefficient of this interactive term, c, allows to test whether subsidiaries enjoy economies of scale beyond those for domestic firms (see also Holemans & Sleuwaegen (1988)).

Related to size is the effect of **diversification** upon R&D. Dating back to Nelson (1959) economies of scope in R&D call for a positive effect of diversification upon R&D. Remains to be seen whether diversification, after correcting for size still has a significant positive impact. DIV_i is a dummy which is 0 if the company is undiversified (i.e. realizes all sales in the same sector); else 1

As many other studies have indicated, **industry dummies** to correct for fixed industry effects, capturing differences in technological regimes, is a practice introduced by Scherer (1965) and widely diffused in subsequent work given its often significant impact (see eg Audretch (1995)). These industry dummies may be capturing various technology dimensions as stressed by several authors (eg Teece (1986), Breschi, Orsenigo & Malerba (1996)) such as technological opportunity, appropriability regimes, dynamic aspects as cumulativeness or the emergence of dominant designs along the technology life cycle, the necessity for complementary and specialized assets, when implementing innovations. Four such significant industry dummies are retained in the analysis:

CHEM	chemicals industry (include pharmaceuticals)	Nace 23-25
IT	Information Technology	Nace 32
INFO	Informatics Services	Nace 72
MVEN	Metals Manufacturing & Electronics	Nace 28, 29, 31, 34

The impact of **government support** on firm R&D has drawn considerable attention in the literature evolving around the issue of additionality. Do subsidies simply substitute for company financed R&D, or can it complement/enhance the latter, raising it beyond critical levels ? To test this hypothesis, the variable $logSUB_i$ is included, which measures the amount of subsidies received from governments (regional, national and international). Amounts of 1992, i.e. one year lagged vis-à-vis the dependent variable IRD, are used to circumvent possible simultaneity following from an inclination towards selectivity of subsidy policy. A positive coefficient would suggest an additive effect of subsidies. A first look at the data already reveals that subsidies are a restricted but very concentrated phenomenon. In the sample, subsidies account for 5% of total reported R&D, including no specific size effect. Only 15% of the repondents reported receiving subsidies. 85% of total reported subsidies go to only 5 companies.

The major focus of the analysis is on the relationship between internal in-house R&D and **external technological linkages**. While the overall technological strength of a company is directly related to its size and technological opportunity, acquiring technology from the outside may not be neutral to its R&D decisions. The availability of external technology may discourage and hence substitute for own research investment. But as shown supra, it is increasingly stressed in the literature that when inter-firm transfers occur, they do not stand as an all-or-nothing substitute for in-house development.

To test the effects of external R&D technology sourcing on in-house R&D, the following variables are included: the variable ERD_i represents firms' expenditures on R&D contracted out, including R&D contracting to other firms, as well as research institutes. This contracting phenomenon is on average for the sample companies rather modest. About one third of the respondents have reported non-zero contracting budgets. Only 10% of the total R&D budget is spent on extra-muros activitities. This percentage is somewhat higher, but not significantly, for large companies with foreign majority and also for companies without an own R&D department.

Besides R&D contracting, the growing importance of collaborative R&D strategies is captured through $COOP_i$, a dummy variable which takes on the value of 1 if the firm is engaged in R&D cooperation, else 0. Since data on cooperation are not part of the official OECD statistical requirements, the current survey only scantly collects information on this phenomenon. No indication can be given on the importance of cooperation in terms of budgets spent on cooperation, as well as the form in which such cooperation prevails. Only the type of partners involved, other firms, related or not, versus research institutes (include universities) can be indicated. Six out of 10 sample companies report cooperation in R&D, a frequency that is higher for large companies and in high-tech sectors. Further indications of complementarity between own R&D and cooperation, is provided by the higher percentage of cooperation for companies with R&D departments. Also interesting to note is the higher percentage for foreign owned companies.

Finally firms' expenditures on buying external technology, BUY_i , includes technology acquisition embodied in equipment as well as licensing expenditures. Given that again this information is only collected as an appendix to the official OECD required information, the quality of this quantitative information is less obvious [2] and the restricted respons on this question reduces the effective sample to 129 observerations when including this variable. Results will be reported as an extension, but the variable is not retained in the basic specification.

The coefficients of log ERD_i, $COOP_i$, and log BUY_i , resp m_1 , n_1 and l_1 , allow to test whether these various sources of external know-how substitutes, if negative, or complements, if positive, own R&D. To test in addition the role of in-house R&D activities on the effect of external know-how on internal R&D expenditures, each of the external sources has an interaction effect included:

$$RDP*(\log EM_i *m_2 + COOP_i *n_2 + \log BUY_i * l_2)$$

where RDP is a dummy that takes on the value of 1 of the firms has an own R&D department with full-time R&D personnel. Following the literature, this seems to be a good proxy for absorptive capacity. A more indepth approach to the firm's willingness to absorb, its organisational culture and the specific profile of its researchers which further shape this absorptive capacity is unfortunately impossible, given the lack of available data on this level. About 43% of the sample companies have a staffed R&D departement. This percentage is considerably higher for large companies and in high-tech sectors indicating economies of scale.

The discussion on the linkage between internal and external R&D strategies has made eminent that there exists a two-way causality, a simultaneous relationship between the two phenomena. Not only may external R&D stimulate or discourage own R&D, the fact that own R&D may enhance the efficiency of external strategies will induce those firms that have own R&D to be more engaged in external strategies. This holds a fortiori for those companies with in-house R&D and may results in an upwardly biased coefficient. [3] To avoid this simultaneity problem as much as possible, lagged variables are used for external strategies where possible. Hence while the internal R&D expenditures IRD are for 1993, the expenditures for ERD and BUY span 1992.[4] The information on COOP is time-unrelated

[2] This holds certainly with respect to embodied technological purchase which takes the bulk of externally bought technologies. While all types of buying technology account for 10% of the total R&D expenditures in the sample, licensens only account for 1% of these expenditures.

[3] Internal R&D expenditures are significantly larger for those companies that have cooperation (at a 3% significance level). But after controlling for size, there is no longer any difference in internal expenditures between cooperating and non-cooperating firms at least for large firms. Only for SMEs a significant difference remains. Similarly when correcting for the presence of an R&D department, for those firms with such departments, there is no significant difference in internal R&D expenditures between cooperative and non-cooperative firms.

[4] One could ofcourse argue that a strong correlation over time of these variables exist. The correlation between EM and EM_{-1} is indeed significant, as well as for the licensing expenditures. Alternatives as a

and hence cannot be lagged. To tackle the simultaneity problem between cooperation and internal R&D, a structural equation model for both internal R&D and cooperation, taken into account the mutual relation between the two phenomena is used. Indeed Colombo & Garrone (1996), after testing the Granger causality relationship between a firm's R&D intensity and its technology cooperative agreements, conclude that their results "suggest that a simultaneous two-equation model is the appropriate framework to study firm's decisions on in-house R&D intensity and technological cooperation" (1996, p 930.)

The structural equations can be represented as follows

$$\begin{cases} \log IRD = z_i\, X_{IRD} + COOP^*(n_1 + n_2 RDP) & (2.1) \\ COOP = z_c\, X_{COOP} + \log IRD^* w & (2.2) \end{cases}$$

While equation (2.1) is equivalent to (1), the proxies that are used as independent variables to explain cooperation are size, ownership, diversification and fixed industry effects. Also included is the importance of research rather than development in the innovative strategy of firms, through the PRES variable (expenditures on research as % of total R&D spending). The strategic management literature often suggest that basic research is more prone to networking. The more fundamental is the nature of R&D, the higher the risks involved, which can be shared or better controlled in cooperation. In addition the industrial organisation literature argues that for more basic research, spillovers are larger and hence induce firms to engage more in cooperative R&D to internalize these spillovers (see eg Kesteloot & Veugelers (1995)).

While internal R&D is a normal continuous variable, cooperation can only be assessed through a dichotomous variable. Two-stage methods for models with mixed dichotomous & continuous variables are described in Amemiya (1979). The reduced form

$$IRD = \Pi_1\, X + v_1 \qquad (3.1)$$

where X includes all the exogeneous variables X_{IRD} and X_{COOP}, can be estimated by OLS while the reduced form

$$COOP^* = \Pi_2^*\, X + v_2^* \qquad (3.2)$$

is estimated by probit ML. Note that because COOP is only observed dichotomously, only Π_2^* can be estimated which is equal to Π_2/σ_2 with σ_2^2=var (v_2). Π_2 and v_2 correspond to the reduced form of the continuous version of COOP. After substituting the estimated $\hat{}\Pi_2^*$ X for COOP in (2.1), the latter can be estimated by OLS and similarly equation (2.2) can be estimated by probit ML after substituting $\hat{}\Pi_1^*$ X for IRD. Note that since only Π_2^* and not

simultaneous-equation-approach, is geven the skewedness of the phenomenon of R&D contracting, not practical.

Π_2 is identified, the estimated coefficient for COOP in (2.1) is *(n_1 + n_2RDP) times σ_2, while the estimated coefficient for X_{COOP} and IRD are resp z_c/σ_2 and w/σ_2.

Table 1 summarizes the variables used.

Table 1: A list of variables

IRD	internally financed intra-muros expenditures for R&D, 1993
S	company sales, 1992
DIV	diversification dummy, equal to 0 if undiversified; else 1
CHEM	industry dummy for Chemicals (include. pharmaceuticals)
IT	industry dummy for Information Technology
INFO	service dummy for Informatics Services
MVEN	industry dummy for Metals Manufacturing & Electronics
M	multinationality dummy, equal to 1 if company is majority foreign owned; else 0
SUB	amount of subsidies received from governments, 1992
ERD	extra-muros expenditures for R&D, 1992
COOP	cooperation dummy, equal to 1 if company is engaged in R&D cooperation
BUY	expenditures for technology acquisition embodied in equipment and for licensing external technology, 1992
RDP	absorptive capacity dummy, equal to 1 if the firm has own R&D department & personnel
PRES	% of total R&D expenditures accruing to Research

3. The Results

Insert table 2 here

Table 2 shows the estimation results on the complete sample. Missing observations on some of the variables reduced the effective sample to 180. The discussion focuses mostly on the second-stage internal R&D results (see equation (T2.1a)). But the structural modelling approach also yields interesting results on the determinants of cooperation, which will be reported and discussed as well.

The most important variable to explain internal R&D, i.e. with the highest contribution to total R^2, is the size variable. Its coefficient, significantly positive and smaller than 1, suggests that internal R&D expenditures increase with sales but less than proportionally. This is in line with most other studies which tend to find positive but weak effects of size on R&D (intensity) (see Cohen & Levin (1989)). Note that the reported size effect only holds for R&D active companies.

For foreign controlled firms, internal R&D expenditures increase more with size as compared to domestic firms (α=12%). A similar result for Belgium was found in Holemans

& Sleuwaegen (1988)). Taking into account that foreign owned firms are typically larger than their domestic counterparts, these results might reflect a non-linear relationship between firm size and R&D as found by others, e.g. Bound et al (1984). Nevertheless, foreign owned companies have lower R&D expenditures after controlling for other determinants, witness the negative coefficient of M_i (α=17%). This might reflect the centralization of R&D within the foreign parent company resulting in lower own R&D activities within local subsidiaries. [5]

The four industry dummies, which are included to capture inter-industry differences in technological opportunity, but could also be measuring other unspecified industry effects, such as demand pull, are all highly significant, again in line with previous studies (see Cohen & Levin (1989)). Also in line with previous studies is the unclear effect of diversification, which, when controlling for size and industry effects fails to influence significantly internal R&D expenditures. This result can also be related to the specific character of the sample where most of the companies are undiversified.

The estimates for government sponsored R&D are significantly positive, suggesting that subsidies seem to stimulate internal R&D expenditures. The point estimate of 0.14 is similar to those found in other studies for Canada & USA (see Mansfield & Switzer (1985)).

Before turning to the discussion of the external sourcing strategies, it should be pointed out that these results on the more classical determinants of R&D performance, remain robust across the various results for external sourcing. Most of the discussion will be based on contracting and cooperation as external sourcing strategies, since the buy-variable is less reliable and substantially reduces the effective sample.

If one would ignore the absorptive capacity through the interaction term, see equation (T3.1) in table 3, the coeffcient measuring the effect of expenditures on R&D outsourcing on internal R&D expenditures, is positive and significant, indicating a complementary relationship. Cooperative R&D engagements seem to have no significant impact on internal R&D expenditures. The coefficient is positive, indicating a complementary character, but it's far from significant. It is only when explicitly taking into account absorptive capacity that external sourcing becomes significant in explaining internal R&D expenditures.

The basic regression is Equation (T2.1a) in table 2, which includes the interaction of log ERD and COOP with the presence of a staffed R&D lab. The results seem to suggest that for R&D contracted out, there is only a significant effect on own R&D when own in-house

[5]. This pattern typically prevails in car manufacturing, where foreign plants are mainly assembly. In other sectors, Belgium/Flanders has occasionally succeeded in establishing subsidiaries that are (European) research centers.

R&D infrastructure is present. Note however that the size of the coefficient suggest only a small complementary effect. An increase in extra-muros expenditures by 10% increases own in-house expenditures by about 1%. Unfortunately no data are available for different sources of extra-muros expenditures [6].

The effects of external sourcing through R&D cooperation, although only measured through a dichotomous variable, are more distinct. On average, after correcting for company and industry characteristics, firms engaging in R&D cooperation seem to spend less on internal R&D, pointing in the direction of a substitute relationship, but the effect is far from significant. For firms that have own in-house staffed R&D departments, cooperation is associated with significantly higher internal R&D expenditures. Note that since the size of the coefficient includes σ^2, only the sign but not the size of the effect can be determined.

The second stage probit ML results for COOP (see equation T1.1b) reveal that indeed firms who spend more on internal R&D have a significantly higher probability of cooperating[7]. Again size is a significant determinant of cooperative behavior, with smaller innovative firms more likely to cooperate than larger firms, ceteris paribus. While in the first stage ML (see equation T2.1d), size was unsignificantly positive, correcting for internal R&D expenditures in the second stage leaves a significantly negative size coefficient Likewise for the industry dummies which failed to show up significantly in the first stage estimation, a significantly negative effect is found in the second stage results, indicating that the typically high-tech sectors are less likely to be engaged in cooperation, after correcting for the positive effect of their internal R&D expenditures. Companies with a more pronounced research orientation are found to have a higher likelihood of cooperation, supporting the theoretical hypotheses put forward supra. Foreign ownership has no significant additional effect on the probability of cooperation. Likewise, diversification fails also here to have any significant impact. While government subsidies have a significant positive effect in the first stage estimation, this effect seems only to come about through its effect on internal funding, since the subsidy variable fails to show up significantly in the second stage estimation and is hence not included in the second-stage.

Insert Table 3 here

[6] Only for intra-regional contracting flows, a distinction is made between firms and research institutions. But these intra-regional flows account only for one quarter of the total contracting expenditures.

[7] Kleinknecht & Reijnen (1992), ignoring the two-way relationship between R&D and cooperation find no significant effect of R&D intensity on the likelihood of cooperation (except with foreign research institutes). They do however find firms with a formal R&D department to be more likely engaged in cooperation.

Including as external strategy the buying of technology, either embodied or disembodied, seriously reduces the degrees of freedom of the model and introduces more multicollinearity with other external strategies, especially for R&D contracted out, certainly for the interaction terms. The reported results (see esaution (T3.2) in Table 3) reveal a significant positive effect of externally bought technology on internal R&D spending, but again only for those companies with absorptive capacity, as measured through own R&D infrastructure. This result can be related to the fact that most of these expenditures are indirect through purchase of equipment which typically would still require own adaptation to yield innovative output.

As alternative measures for absorptive capacity, R&D departments with personnel that has a doctorate degree was tried. If the scientific profile of the researcher is related to his willigness to absorb, this could leave a higher absorptive capacity for firms employing doctors. 44% of all companies with staffed R&D departments have personnel with a doctorate degree. The basic results, reported in equation (T3.3), remain, i.e. only for firms with absorptive capacity, cooperation is associated with higher internal R&D levels, while absorptive capacity influences positively the effect of contracting on internal R&D. Similarly, absorptive capacity could be related to the science base of a company. Constructing a dummy which takes the value of 1 if the firm has a staffed R&D department and is engaged not only in development but also in (fundamental) research, i.e. 58% of all firms with staffed R&D departments, leaves again similar results.

Unfortunately the information on cooperation doesn't allow to disentangle the many different forms of cooperation, but they do allow to distinguish among different types of partners in collaboration. Cooperation with research institutes (including universities) seems again to have no effect on internal R&D efforts. But when absorptive capacity is present in the form of a staffed R&D department, collaborating with such institutes is again associated with higher internal R&D expenditures. These results are shown in equation (T3.4) where the dummy variable $COOP_{RI}$ is defined to only include those firms cooperating with research institutes.

Splitting the sample according to firm or industry characteristics could reveal whether such characteristics as size, ownership structure or technology regime are important in determining the relationship between external and internal sourcing and the effectiveness of absorptive capacity. A number of such splits were tried but resulting in too low degrees of freedom for the two-stage procedure. Especially the probit ML procedure leaves questionable validity of the model in most subsamples. Distinguishing small and medium sized enterprises, i.e. those companies with less than 200 employess, leaves only 47 data disembodied acquisition of foreign technology is considered. The results confirm a positive, but less than proportionate size effect, which when further disentangled provides evidence of a non-linear relationship between size and R&D expenditures. For foreign controlled firms, the size effect is larger. Government support is found to stimulate internal R&D.

Concerning the effect of external sourcing, the results seem to indicate that cooperation in R&D has no significant effect on own R&D unless the firms have an own R&D infrastructure, in which case cooperation stimulates internal R&D expenditures. These results support the idea that indeed absorptive capacity is necessary to be able to capitalize on the complementarities between internal and external know-how. Also other external sourcing strategies as R&D contracted out and technological purchases, mostly embodied in equipment, is found to significantly stimulate own R&D only when absorptive capacity is present.

The two-stage estimation procedure taking into account the simultaneity between internal R&D and cooperation allows to conclude that not only does cooperation induce internal R&D spending, at least when absorptive capacity is present, but also that at the same time firms who spend more on internal R&D have a higher probability of engaging in R&D cooperation.

Despite its restricted scope in terms of number of companies and variables included, these results are interesting, if only because they fit into a not particularly strewn set of empirical studies on the effects of external sourcing. They clearly demonstrate the complexity of the relationship. Whether external sourcing can stimulate own R&D clearly depends on firm characteristics such as the presence of absorptive capacity. More work is needed to identify specific characteristics generating this absorptive capacity. The results indicate that having own in-house full-time staffed R&D departments, serves as an instrument to induce positive effects of cooperation on internal R&D, while this complementarity may be even higher for foreign controlled firms. Other firm characteristics such as size, the technological environment in which the firm is embedded, its cumulative experience and central positions in networking, need further investigation on larger and more detailed data sets. Taking an even more indepth look at internal firm structure, linking to the organisational structure of companies (e.g. centralized vs decentralized, team oriented vs functional), as well as HRM policies vis-à-vis R&D personnel, could give additional evidence on the potential to assimulate external ideas, further characterizing what could generate absorptive capacity. The present results, including some limited evidence on the scientific profile of researchers, failed to provide clear evidence for higher levels of openness, generating more complementarities. More research is also necessary to examine why different modes of external sourcing may have a different impact. In this respect the analysis should be extended to also include unvoluntary transfers of know-how. And finally, where the analysis presented here was limited to the effect of external strategies on internal R&D expenditures, the productivity of these strategies in terms of generating more or more profitable innovations and future profits still needs to be assessed.

TABLE 2: Regression results

	Equation (T2.1a)	Equation (T2.1b)	Equation (T2.1c)	Equation (T2.1d)
	Second-stage OLS logIRD	Second stage probML COOP	First-stage OLS logIRD	First-stage probML COOP
Intercept	2.091 (1.395) .135	-6.030 (2.129) 005	1.908 (1.079) .079	-1.918 (1.851) .300
log S	0.437 (.091) .000	-0.878 (.371) .018	0.469 (.085) .001	0.117 (.148) .429
log S*M	0.232 (.130) .076	-0.159 (.361) .659	0.204 (.132) .123	0.290 (.355) .415
M	-2.840 (1.790) .114	3.214 (4.71) .495	-2.534 (1.775) .155	-2.377 (4.659)..610
DIV	0.089 (.221) .688	0.496 (.388) .201	-0.042 (.220) .848	0.420 (.386) .276
CHEM	0.827 (.305) .007	-1.988 (.796) .013	0.874 (.310) .005	-0.070 (.547) .898
IT	1.618 (.457) .000	-3.990 (1.391) .004	1.633 (.447) .000	-0.436 (.773) .573
INFO	1.606 (.433) .000	-3.509 (1.422) .014	1.623 (.441) .000	0.026 (.790) .974
MVEN	0.746 (.244) .003	-1.740 (.683) .011	0.772 (.249) .002	-0.096 (.433) .824
logSUB	0.144 (.047) .003		0.142 (.037) .000	0.292 (.134) .029
logERD	0.040 (.040) .324		0.024 (.037) .505	0.103 (.075) .167
logERD*RD	0.091 (.042) .033		0.101 (.043) .019	0.150 (.139) .281
COOP *predicted*	-0.564 (1.069) .599			
COOP*RDP *predicted*	1.634 (.537) .003			
PRES		1.926 (.687) .005	-.392 (.374) .300	1.053 (.655) .108
logIRD *predicted*		2.136 (.681) .002		
Adj R-sq	.590	.215	.572	.219
N	180	198	180	198

<u>Note</u>: Between brackets are standard errors. Also indicated are the significance levels.
For the probit ML the R^2 is calculated from 1-(2LogL (interceptonly)/-2LogL(intercept and covariates)

TABLE 3: Regression results continued

	Equation (T3.1)	Equation (T3.2)	Equation (T3.3)	Equation (T3.4)	Equation (T3.5)
	Second-stage OLS logIRD	Second stage OLS logIRD	Second-stage OLS logIRD	Second-stage OLS log IRD	Second-stage OLS log IRD
Intercept	1.730 (1.423) .226	1.934 (1.711) 261	1.909 (1.391) .001	1.714 (1.359) .209	1.648 (1.437) .001
log S	0.474 (.092) .000	0.450 (.127) .001	0.467 (.091) .000	0.433 (.085) .000	0.437 (.092) .000
log S*M	0.204 (.133) .127	0.401 (.183) .030	0.200 (.133) .138	0.268 (.133) .045	0.286 (.145) .051
M	-2.501 (1.830) .174	-5.445 (2.524) .034	-2.503 (1.831) .174	-3.388 (1.786)..060	-3.629 (2.105)..087
DIV	-.026 (.223) .905	0.048 (.292) .869	-0.091 (.222) .683	0.096 (.217) .659	0.164 (.224) .464
CHEM	0.874 (.312) .006	0.839 (.409) .043	0.831 (.314) .009	0.785 (.303) .011	0.723 (.308) ..020
IT	1.703 (.467) .000	1.770 (.532) .001	1.642 (.465) .001	1.548 (.462) .001	1.489 (.462) .002
INFO	1.630 (.443) .000	1.954 (.580) .001	1.627 (.445) .000	1.611 (.435) .000	1.507 (.439) .001
MVEN	0.806 (.249) .001	0.779 (.319) .016	0.823 (.247) .001	0.743 (.243) .003	0.631 (.250) .013
logSUB	0.138 (.048) .004	0.096 (.046) .039	0.131 (.047) .006	0.163 (.050) .002	0.171 (.047) .000
logERD	0.019 (.040) .633	0.063 (.051) .218	0.046 (.038) .228	0.074 (.050) .145	0.075 (.060) .213
logERD*RDP	0.104 (.043) .016	0.029 (.060) .624	0.088 (.046) .057	0.073 (.042) .087	0.101 (.064) .116
COOP *predicted*	-0.017 (1.080) .987	-.266 (.808) ..742	-.309 (1.008) .760	0.192 (.931) .837	0.323 (1.196) .787
COOP*RDP *predicted*		1.241 (.652) .060	1.957 (.989) .049	1.045 (.324) .001	1.622 (.550) .004
logBUY		-.072 (.052) .172			
logBUY*RDP		0.151 (.068) .030			
logERD*M					-.003 (.082) .971
logERD*RDP*M					-.009 (.085) .915
COOP*M *predicted*					0.704 (2.420) .772
COOP*RDP*M *predicted*					3.562 (2.469) .151
Adj R-sq	.569	.589	.572	.594	.594
N	180	115	180	180	180

Note: Between brackets are standard errors. Also indicated are the significance levels.
For the probit ML the R^2 is calculated from 1-(2LogL (interceptonly)/-2LogL(intercept and covariates)

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